Is there a lifeguard at the gene pool?[1]

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Patterson, D. L. 2000. **Is there a lifeguard at the gene pool?** Can. J. Anim. Sci. **80**: 245–255. Modern agricultural practices have led to a decline in our farm animal genetic resources. Changes in the environment or society demands for more ecologically sustainable production systems may require breeds other than those in common use today. Although definitions of levels of concern differ, Canada has a number of endangered breeds which are of cultural and historical interest and which may be useful in future niche markets. Canada has formally ratified the international convention on biological diversity, but funding cuts have jeopardised national programs. The Food and Agriculture Organisation of the United Nations has the mandate to establish an international program for conserving domestic animal diversity and its sustainable use. A major initiative has been the establishment of a data base and training information available through the World Wide Web. New technologies such as microsatellite markers and mathematical modelling offer promise for integration with more traditional live animal conservation methods and are now being incorporated into conservation schemes in a number of countries. Canadian groups involved in livestock and poultry genetic resource conservation must continue to interact to ensure a coordinated approach.

Key words: Biodiversity, breed conservation, animal genetic resources

Patterson, D. L. 2000. **Où s’en va notre diversité génétique?** Can. J. Anim. Sci. **80**: 245–255. L’agriculture moderne a entraîné le déclin de nos ressources génétiques animales. Les modifications de l’environnement et la recherche de systèmes de production écologiquement soutenable risquent d’entraîner la création de races différentes de celles couramment utilisées à jusqu’ici. Bien que l’urgence de la situation diffère selon les pays, le Canada, pour sa part possède un certain nombre de races menacées de disparition qui revêtent un intérêt culturel et historique et qui pourraient trouver une place dans les futurs créneaux de production. Le Canada a ratifié la Convention internationale sur la biodiversité, mais la mise en place de programmes nationaux est compromise par le manque de financement. L’Organisation des Nations Unies pour l’alimentation et l’agriculture (FAO) est chargée de mettre en place un programme international de conservation de la diversité génétique et d’utilisation durable du cheptel agricole. Une réalisation majeure a été la constitution d’une base de données et d’une banque d’outils de formation disponibles sur Internet. Les nouvelles technologies comme le marquage par microsatellites et les modèles mathématiques offrent des possibilités d’intégration aux méthodes plus traditionnelles de conservation des animaux en vif et elles sont de fait déjà utilisées dans un certain nombre de pays. Il est important que les groupes canadiens impliqués dans la conservation des ressources génétiques zootechniques, bétail et volaille continuent à coordonner leurs activités dans ce domaine.

Mots clés: Biodiversité, conservation des races, ressources génétiques animales

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Every schoolchild in Canada today is familiar with the concepts of conservation. Loss of habitat from wetlands to forests, and endangered species from piping plovers to pronghorn antelope, make media headlines. Such reports usually do not mention domestic animals or the disappearance of animal breeds. It is tempting to think that we do not need to worry about domestic animal genetic diversity. A typical mammal has about 100 000 functional genes (Weaver and Hedrick 1997) Multiply this by thousands of animals and the number of combinations is uncountable. However only a small fraction of available animal species have been used for domestication, with each species subjected to management and selection that led to a wide range of variation within the species. Within any one species, total genetic variation will not be lost even if subgroups are, as long as new subgroups are formed and combinations of these can occur. However if more subgroups disappear than are formed, and if combinations of traits that contribute to productivity in specific environments are lost, our animal genetic resource will decline. Once lost, the actual combination resulting in a superior animal will be extremely difficult or impossible to redevelop. The loss of genetic diversity within a species may be forgotten by many, but from an agricultural perspective this diversity is as important as that seen between species.

Why have Breeds Been Lost?

Early agriculture was based on small farms in a variety of environments, often with little communication with each other. This led to the development of unique breeds suited for that particular management system and market. Animals had to be hardy as veterinary care and modern pharmaceuti-

Abbreviations: **AI**, artificial insemination; **ALBC**, American Livestock Breeds Conservancy; **CAGTEB**, Canadian Animal Germplasm Technical Experts Board; **CFCFAGR**, Canadian Foundation for the Conservation of Farm Animal Genetic Resources

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cals were not available. The fact that an animal could survive and still produce to some level was more important than high production per animal. Although this situation still occurs in many parts of the world, modern agriculture wants high yields and uniformity, with animals raised in a carefully managed environment. Genetic variation is not desired – we want each of the animals in the group to react in the same way. It should be remembered that the market for animal products depends on the consumer, and the industry must respond to these demands.

Although each animal industry differs somewhat, we can use the dairy and poultry industries as examples of how the genetic base has been eroded. Poultry genetic selection advanced rapidly following the development of scientific breeding theory. This is partly due to the biology of the animal, its natural fecundity and short generation interval, and partly due to the ability to mechanise incubation and control reproduction by lighting (Hartmann 1989). Inbreeding and crossbreeding studies began in the 1930s, with the first successful hybrid bird in the United States sold by Hy-Line Poultry Farms in 1947. The intense competition that followed led to the development of large breeding companies for laying stock and meat stocks. The same pattern was followed in Europe. Although many feel that the resulting decrease in number of breeding strains leads to loss of genetic diversity, Hartmann (1989) believed that sufficient genetic diversity is maintained in stocks kept by fanciers. The International Registry of Poultry Genetic Stocks (Somes 1988) listed a large number of specialised lines and sources of genetically controlled plumage types, skin colour, etc. However, some of these lines, such as the strains developed by Agriculture Canada in Ottawa and Kentville, have now been dispersed. The diversity to allow adaptation to extreme environmental conditions, to different diseases, or to a less intensive poultry management system may no longer be present in poultry stocks. A potential concern is that some genes have been used extensively by the commercial poultry breeding industry. These include the dominant and recessive whites to standardise colour and the fast and slow feathering alleles to assist in sexing. Such alleles may be linked with other deleterious alleles, which may only manifest themselves as a problem when they are thoroughly spread throughout the population. Crawford (1990) also argues that the concentration of such genetic resources makes a country like Canada, with no national poultry breeding industry, vulnerable to economic and political changes.

The structure of the dairy industry requires a high investment cost for equipment and for quota in Canada. Milk processing has become concentrated in fewer companies. Small plants collecting milk from local producers and making their own butter and cheese have almost completely disappeared. Thus dairying became the realm of large producers who use intensive management to keep high-yielding cows in production. This has meant the decline of breeds like the Jersey (9% of North American dairy cow registrations in 1990) and the Guernsey (3% of registrations). The Holstein breed made up 82.5% of registrations (Bixby et al. 1994), with this percentage underestimating the actual proportion as many commercial dairy cows are not registered. Even though a breed is very numerous, most of the genes may be contributed by only a small number of parents. Our Canadian dairy population has made extensive use of artificial insemination since the 1950s, reducing the number of males used. An international evaluation scheme such as Multi-trait Across Country Evaluations (MACE) means bulls can be used from around the world. However, many of these have a common lineage. Top animals become concentrated in only a few herds and potential widespread use of embryo transfer and in vitro fertilisation may mean even less genetic diversity in the future.

Boyens (1999) discusses the loss of genetic diversity due to modern farming practices and the increase in biotechnology in her book on Canadian corporate agriculture. She considers modern livestock production to be an industrialised process, with much of the shift due to the development of reproductive techniques such as artificial insemination (AI) and embryo transfer. This has led to the use of only about a dozen bulls on 75% of the Canadian Holstein cow population, a factor she feels has led to widespread inbreeding. Although books such as this may be considered sensationalist, they are widely read and do raise many valid points. Other countries are also concerned about increasing inbreeding levels in dairy populations, as it is in dairy production that we see the greatest use of artificial insemination. In Icelandic dairy cattle, for example, 58.6% of cows with production records were inbred, leading to a reduction of 0.22 to 0.39% of production per 1% increase in inbreeding (Sigurdsson and Jonmundsson 1995). The average increase in rate of inbreeding of bulls, 0.08% per year, was significant. The population is small (about 70 000 animals) and has had a long period of genetic isolation, and thus serves as a useful model for other small isolated populations.

Looking at other species, diversity of horse breeds obviously declined with increasing mechanisation. Many horse owners are more concerned with individual conformation and temperament than with any breed designation. The situation in swine parallels that of poultry. The number of breeds has been reduced to a group of four (Landrace, Yorkshire, Duroc, and Hampshire) which do well in confinement housing and in defined cross-breeding schemes. The increasing development of swine breeding companies may lead to even further narrowing of the genetic base, as each company develops its own specialised sire and dam lines and concentrates on selection within these lines. Beef cattle and sheep are in a somewhat better position. Although breeds such as the Belted Galloway and the North Country Cheviot have certainly declined in number, a large variety of beef and sheep breeds are still found in Canada. The importation of European beef breeds in the 1960s and 1970s widened the genetic base for that species. Management practices still rely heavily on adaptation to local environments, but feedlot finishing means that uniform breed groups are again desirable. Thus, overall genetic diversity may quickly decline.

In developing countries, breeds from Europe and North America are often used as substitutes for local breeds. This

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can be due to necessity, as when wars or harsh environmental conditions can decimate local populations, or because of deliberate government policy. Brazil for example has 150 million head of cattle but per cow production is less than 1/10th of the US average. With increasing demand for dairy products, the market for high-production dairy cattle rather than the native dual-purpose breeds is increasing (House 1995). Genetic stock is imported mainly from North America. However, such introductions can be short-sighted, as they often depend on an increased level of management that is not feasible in many locations.

Importation of breeding stock is not limited to livestock and poultry. Imported species of fish are often used in preference to native species. *Tilapia* spp. are highly productive and easily managed in a variety of environments. These species, especially *Oreochromis niloticus*, have been introduced into regions from Mexico to Asia. Indian carp species now have a major impact on fish production in northern Vietnam (Edwards et al. 1997). Native cichlid species of Central and South America do exist, however little is known about many of these. Aquaculture programs often use broodstock taken as eggs from river sources, then moved to other locations. A 1996 workshop on North American nonindigenous fresh water fish identified the need to monitor species introduced for aquaculture purposes (Efford et al. 1997). These imported stocks may escape and potentially replace the native stocks. Muir (1995) reported on studies in the UK, Norway and Canada where large numbers of cage-reared fish showed up in spawning rivers following damage to cages. Thus aquaculture can potentially lead to loss of genetic resources not only in the species farmed, but also in wild stocks.

Why is Loss of Genetic Diversity a Concern?

Today's urban consumer of food products is much more demanding than the typical consumer of 50 yr ago. Reports on the bovine spongioform encephalopathy (BSE) outbreak, and the dioxin contamination of Belgian animal products in 1999 increased the desire of many consumers to have "natural" foods. There is great concern about use of antibiotics in animal production because of a perceived link with antibiotic resistance in humans. These health concerns, together with an increasing awareness of environmental and animal welfare issues, lead to demands for changes in our animal production systems. Some of the dominant breeds of today may not fit well into what is perceived as a more sustainable system.

Although red meat consumption is declining in North America, animal products are still important components of diets and industrial products throughout the world. The market for livestock products is expected to double in Asia and Africa. Output of meat, milk, hides and skins from indigenous African ruminant livestock was worth US$18 966 million in 1995 (Rege and Bester 1998). Pastoral peoples in particular rely heavily on animal products. Along with this, however, come demands for more ecologically sound agriculture. Animal production systems will need to adapt to local environments, and local animal breeds may fill important niches in the development of economically and ecologically sustainable agriculture (van der Zijpp 1999).

Some of the older breeds are already finding new markets. The Berkshire pig, while listed as rare or endangered in Canada (Blake 1992; Shrestha 1997) is more numerous in the United States. The American Berkshire Association has teamed with private companies to export meat to Japan, where the darker coloured, firmer meat is much appreciated (Anonymous 1998). The market increased from 200 pigs slaughtered biweekly in 1994 to 4000 slaughtered weekly in late 1997.

We have all heard of medical products developed from unusual plant species. Some of the older breeds or genetic groups of animals may likewise contain gene combinations that are useful for pharmaceutical purposes or for scientific studies in disease resistance and tolerance to adverse environments. We have probably lost forever the opportunity to determine what it was in the physiology of the "island" sheep of Nova Scotia that allowed them to survive on seaweed. These sheep are described in local histories such as that by Perry (1998), but have now been extensively crossed with breeds like the North Country Cheviot and the Scottish Blackface.

But breed preservation is more than keeping a collection of genes. A breed may have a unique cultural or historical role in a society. The Newfoundland pony and the Newfoundland sheep, the Canadienne cow and Canadian horse, and the Lac La Croix pony, are important to many Canadians because of this. This is demonstrated in the recent initiatives of the Newfoundland government to have the Newfoundland pony recognised as a breed. Thus, recognition of the value of indigenous breeds has as much to do with social issues as it does with production. Developing nations are taking on much more ownership of their genetic resources. It is felt by many that the scale and method of modern livestock production adversely affects the small subsistence farmer, and in many countries subsistence farming is the core of society.

In summary, concentration on a limited number of breeds or limited selection of animals within a breed means less genetic diversity. This means less ability to adapt to changing environments. Environmental change does not necessarily mean a dramatic shift in temperature or management. New strains of disease-causing microorganisms may surface, potentially resulting in loss of an entire genetic population. Societal concerns may lead to a gradual shift to less intensive management practices for at least a segment of the industry.

What is a Breed?

A common definition of a breed is that used by the Food and Agriculture Organisation of the United Nations (FAO 1998). It is a homogeneous group of animals, within a species, that has defined and easily identified external characteristics which separate it from other groups of the same species. This organisation also recognises an alternate definition, of a homogenous group, which is geographically separated from similar phenotypes, such that it is generally accepted as being a separate breed. It is important to remember that a breed is a man-made entity, and in many countries is recognised by law. In Canada, the federal Animal

Table 1. Conservation categories

	ALBC (Bixby et al. 1994)	FAO (Hodges 1992)
Critical	<200 annual registrations in North America,and global population of <2000	<100 breeding females
Endangered		100–1000 breeding females
Vulnerable		1000–5000 breeding females
Rare	<1000 annual registrations in North America and global population of <5000	500–10 000 breeding females
Watch	<2500 annual registrations in North America and global population of <10 000	10 000 breeding females

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Pedigree Act (Government of Canada 1988) sets out the requirements for recognition of a breed and the format for registration of animals. This provides a set of uniform criteria for an animal to be called a purebred and for a breed to become formally recognised. Registration is, of course, the responsibility of each breed society, with Canadian Livestock Records Corporation (web site URL http://www.clrc.on.ca) contracting with breed associations to maintain the registration database. However, the requirements to register a breed can present problems. Andrew Fraser (1992), in his book *The Newfoundland Pony*, eloquently describes the difficulties faced when a group of animals has been kept for performance only. Since paper registration and uniformity of looks was not important, two of the main requirements to list a breed, tracking of pedigrees and adherence to a set standard, do not occur.

The American Livestock Breeds Conservancy (ALBC) defines four breed types of domesticated animals (Christman et al. 1997). *Feral* populations occur when domesticated animals escape from, or are released from, human management. Many of these become extensively crossbred but some are isolated genetically and can be considered breeds in themselves. *Landraces* are populations which have been under both natural and artificial selection, thus tend to be well adapted to specific environments. Since they are usually not selected for production characteristics, landraces tend to be more variable in appearance than *standardised breeds*. These latter are designated as such because they have been selected by humans to be similar in appearance, conforming to a set standard, with well-developed production traits. For the most part, these are the breeds recognised by our federal legislation. *Industrial stocks* have been selected for increased performance in a highly managed environment and may be crosses of two or more standardised breeds. The industrial stocks are often held by multinational corporations, with genetic information closely guarded.

The above formal definitions rely primarily on phenotype. However, the same phenotype can result from different genetic causes, and the link of the defined phenotype with other physical characteristics may not be that obvious. It is often preferable to define breeds in terms of their actual genetic make-up. New methods of DNA analysis now make this possible. We can also use these new techniques to help quantify genetic diversity between breeds, by measuring genetic distance. Microsatellite markers are used to measure genetic diversity in species ranging from cattle (Fries 1993; Hansen et al. 2000) to horses (Marklund et al. 1994) to shrimp (Wolfus et al. 1997). Genetic maps are now well on the way to completion for most species. It is important that consistent reference standards are adopted, for example as outlined for the East Lansing map in poultry by Cheng (1997), and that adequate comparative maps be developed.

As an example, a comprehensive study using microsatellite markers to assess genetic variability of Newfoundland sheep and nine other breeds ranging from Red Masaii to Suffolk, showed considerable differences in allele frequency distributions among the pure breeds (Farid et al. 1999). The phylogenetic tree and estimates of Nei's genetic distance showed little uniformity among the different sources of the Newfoundland sheep, with many showing close genetic relationship with breeds such as the Cheviot and Suffolk. However, sheep in two demes that were geographically isolated and had been kept as closed flocks did show uniformity. The authors suggested that 22% of the Newfoundland sheep could be considered as unique, and that contrary to local beliefs, the Icelandic sheep breed had never been introduced to Newfoundland.

When is a Breed Endangered?

A breed is considered to be endangered once the number of breeding pairs falls below a certain limit. Groups have set different levels for the various definitions, using either the total number of animals, the number of breeding pairs, the number of females, or a measure of effective population size (Table 1). The American Livestock Breeds Conservancy also considers dairy breeds that have shown a marked decline in numbers over the past 20 yr to be in the WATCH category and lists populations that lack breed definition and documentation on a STUDY list.

Actual population size gives only part of the picture. The FAO uses the number of breeding females, as this is usually the limiting factor in producing any offspring. The number of males and females is ideally equal to allow for maximum genetic diversity. However animal populations do not have equal numbers of males and females, with each mating producing the same number of offspring. In species where artificial insemination is widely used less than 1% of males may be kept. Thus geneticists use the concept of effective population size (Falconer and Mackay 1996) which when computed over a number of generations gives a more realistic picture of actual genetic diversity.

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Bottlenecks occur when a population declines in numbers. For example, price changes resulted in a dramatic decline in the number of breeding pairs of farmed foxes in the 1930s. Although the population may later increase, the loss of genetic diversity carries through; certain alleles may have been lost forever. Again, a measure of effective population size will give a better view of the genetic resource.

Are numbers of animals, whether actual or effective, the best way to estimate biodiversity? Ollivier (1999) stated that we are moving from a trait-based definition of diversity to a gene-based definition, as this is easier to implement, larger in scope, and more reproducible. (Unfortunately, many of these measures are on the 90% of the genome that is considered non-functional.) He argues that since animal breeding is a business, issues such as monitoring genetic trends, establishing standards of reference to ensure the short-term goals of breeding companies do not compromise long-term objectives, and DNA patenting, become important. These issues may override considerations of actual numbers when decisions on which breeds need protection are made.

Whatever the merits of this proposal, the actual number of animals is more easily understood by the public than are formulae or abstractions. Thus, some measure of actual number is commonly used in conservation efforts. Breeds most at risk appear in the Critical group, whichever such measure is employed. Because of the relative ease in moving breeding stock across the Canada–US border, it is important that Canadian organisations work closely with American conservation efforts in defining numbers and identifying those breeds most in need of immediate efforts. Likewise overall world populations need to be considered.

Endangered Breeds in Canada

The most comprehensive listing of breeders in Canada was done in the mid-1990s, when Agriculture and Agri-Food Canada compiled the databases for sheep (Shrestha 1994), swine (Shrestha 1995b), goats (Shrestha 1995a) and cattle (Shrestha and Hansen 1997). Unfortunately, declines in funding mean that this database collection is unlikely to be repeated in the near future and we must rely on livestock registration numbers. Unless producers are interested in selling purebred breeding stock they may not register their animals, so it can be difficult to find out exactly what is available unless a strong breed association exists. Maintenance of breeder registries of at least those breeds of national interest and in the Critical and Endangered categories should be a priority in any conservation effort.

Although such lists of endangered breeds include a wide range, from Barbados Blackbelly sheep to Berkshire pigs and New Hampshire chickens, the Canadian Animal Germplasm Technical Experts Board (Lister and Ho 1995) recommended that animals which were unique to Canada be given priority in national conservation schemes. This includes defined landraces, animals adapted to Canadian climate and management, and those that are historically or culturally interesting in the Canadian context. The following listing (Table 2) thus represents only a small part of those breeds considered endangered or in need of watching. Some genetic groups, such as the Beef Synthetic and the Dairy Synthetic developed by the University of Alberta, are not considered as breeds. However, such genetic resources are easily lost with a management or policy change. Monitoring status of these stocks would allow interested groups to become involved if the resource is in danger.

Table 2. Breeds of Canadian origin, considered at risk

Breed	Number of animals 1993 figures (Scherf 1995)	Status (Bixby et al. 1994)
Canadienne cow	681 females	Rare
Canadian horse	1360	Critical
Newfoundland pony	1000	
Sable Island pony	300	Critical
Lac La Croix pony	350	
Lacombe pig	277	
Newfoundland sheep	10	
Arcott sheep	664	Not in need of conservation, as original stocks are numerically strong
DLS sheep	248 (1989 figures)	

The Canadienne cow is unique to North America. It provides an option for producers interested in a grass-based dairying system, as it is hardy, high in reproductive ability, and reputed to have high foraging ability and good feed conversion. Descended from cattle of Normandy and Brittany brought to Canada in the early 1600s, this was the dominant dairy breed in eastern Canada until the early 1800s. Numbers declined following a government policy in 1850 to encourage the use of new imports. More recently, breeders began crossing the cattle with Brown Swiss in an attempt to increase production level. However, the Canadienne Cattle Breeder's Association maintains a list of purebreds and works valiantly to preserve the breed (Bernier 1997).

The Sable Island pony needs little description to many Canadians. Although there is some uncertainty as to when horses were first taken to Sable Island, a wind-swept strip of sand off the coast of Nova Scotia, they were clearly identified as being there in an advertisement in a Boston newspaper in 1753 (Christie 1995). They are assumed to be at least partly descendants of the original Acadian horses. Originally used by the farmers on the Island, the ponies have been feral for many years. They are small in stature with large heads but this conformation may be due as much to adverse environmental conditions as to genetic causes. The animals survive by foraging on aquatic vegetation and beach grasses, digging for water, and finding shelter from the numerous storms and high winds. The animals are extensively studied for themselves and for their effect on the environment, and have been protected by law.

The Newfoundland pony was named a Heritage Animal under the 1996 Heritage Animal Act in Newfoundland, with the Newfoundland Pony Society recognised as the official group. The pony was brought to Newfoundland by early settlers. In 1935, there were approximately 9000 ponies in Newfoundland, with large numbers still seen in the 1970s (Government of Newfoundland and Labrador 1998). In 1998 there were 216 ponies registered with the society, of

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which 52 were stallions and colts, 143 were mares and fillies. The majority of these are in Newfoundland itself, and most ponies now registered are from listed stock (Williams, personal communication, 1998). The government provided funding to conduct DNA testing of the ponies, to help support the registry as a step to having the animal declared as a breed under the Animal Pedigree Act.

Molecular genetic technology is also being used to determine genetic heterozygosity in the Canadian horse. The Equine Research Centre and the Department of Animal and Poultry Science at the University of Guelph, in conjunction with a private company, have been examining the genetic relationship among breeds of horses (Behara et al. 1998) and looking at the role of AI to ensure that the small groups of horses from Atlantic Canada to the west do not become genetically isolated (Counsell 1997). The breed is believed to have originated from Arab, Breton and Norman breeds, and was brought to New France between 1647 and 1670. Canadian horses were imported to the United States during the 18th and 19th centuries because of their reputation both as a stylish saddle horse and as a hard-working draft animal. However, according to Christman (Bixby et al. 1994) this actually contributed to the breed's decline, as the horses sent to the United States were not kept as a separate genetic group. The breed is vulnerable, but may be increasing in numbers. It is a popular attraction at heritage farm parks such as Ross Farm in Nova Scotia (Creighton 1995). A heritage animal program was developed at the farm museum in 1990, and three horses were purchased at that time, the nucleus of the current herd. As of 31 December 1998 there were 7632 horses registered in the Canadian society's herdbook, with the majority of the new registrations (220 pure animals in 1998) occurring in Québec (Canadian Horse Breeders' Association 1999).

The Lac La Croix pony is an interesting case. The breed is listed as numbering about 350 in the 1994 World Watch List (Scherf 1995). It does not appear at all in Bixby et al. (1994) in the census of livestock in North America as this listing includes only purebred registrations as of 1990 and the pony does not qualify. In the early 1800s, offspring of Canadian-Mustang crosses roamed the Mohawk reserves in Ontario. By 1977 only four mares remained, near Fort Frances, Ontario, where the ponies had been living a feral existence since the 1960s. The mares were taken to Minnesota where they were bred to a Spanish Mustang stallion. In the early 1990s, the Host Farm program of Rare Breeds Canada brought one stallion and three mares, descendants of these matings, back to Canada. There are now 16 in Canada and a similar number in the United States (Henderson 1999). Parentage testing using DNA analysis was begun in 1998. Can this breed be re-developed from this small number of animals, and if it can, is it worth the effort? The local residents saw the ponies only as a nuisance in the 1960s and 1970s, but First Nations' peoples may come to value the breed as part of their heritage.

The Chantecler is the only truly Canadian poultry breed, developed in Quebec by a Trappist monk in the early 1900s. The bird is white, with a strong build and is winter-hardy. Although some poultry geneticists believe that the true Chantecler is extinct (Crawford 1984), there is a core of breeders who insist that they have original stocks (Patrick 1998). Herein lies the dilemma: if the present birds look like the Chantecler, and if breeders can document at least to their own satisfaction the history of their lines, can geneticists state unequivocally that the breed no longer exists? Alderson (1994a), in his classic book on farm animal conservation, claims that in the developed countries it is difficult to find any breed that represents the original type and has remained pure. Breeders have used a continual process of inbreeding and cross-breeding, and thus have broken the two main principles of genetic conservation: purity of descent and maintenance of genetic variability. The focus then must be on the value of the resulting genetic group for historical and cultural reasons, as much as for genetic purity.

National and International Initiatives

In situ conservation means the maintenance and recovery of viable populations in their natural habitats. In the case of domesticated species, this means in the surroundings in which they have developed their unique characteristics (Supply and Services Canada 1995). Ex situ conservation means the conservation outside the natural habitat. This can range from keeping animals in a museum or zoo to maintenance of semen and embryos, or gene banks. Thus in the strictest sense, in situ conservation of farm animal breeds would mean maintaining these on working farms.

Hall (1992) suggested the following as a definition for breed conservation "The rational use and protection of existing local genotypes from genetic introgression." This contrasts with a more traditional philosophy that breeds should be strictly preserved, a practice perhaps endorsed by individuals who did not have to depend on these animals for survival. However, it is becoming increasingly apparent even in Europe and in North America that if many of these rare breeds are to be conserved in situ they must be demonstrated to be of some economic value. Even in Great Britain, where breed conservation has usually been considered as just that, the Rare Breeds Survival Trust has begun to publicise use of rare breeds in specialty markets. The Traditional Breeds Meat Marketing project was begun in 1994; once fully operational it is expected that 40 to 50 accredited butchers will take part. Breeds are accepted into the program only when their meat quality is well documented. Animal and farm of origin are identified, and each item sold is labelled with the name of the breed (Alderson 1999)

Environmental and genetic diversity is not just a Canadian concern. The United Nations Convention on Biological Diversity was implemented at the Brazil conference on Environment and Development in 1992. The Rio Convention recognised that biological diversity is being significantly reduced by human activities, and the fundamental requirement for conservation included "maintenance and recovery of viable populations of species in their natural surroundings" (UNCED 1992). Biological diversity was defined to include diversity within species, as well as between species. Canada became the first industrialised nation to ratify the convention in December 1992, and released its strategy on biodiversity 2 yr later (Supply and

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Services Canada 1995). It was recognised that conservation of biodiversity and sustainable use of biological resources had to occur in conjunction with meeting national social and economic goals. Canada had to be involved in global efforts in conservation and germplasm exchange for agricultural production, and this should include preservation of rare breeds in on-farm situations. The plan required that governments at all levels put mechanisms in place to encourage non-governmental organisations and members of the public to be involved. It had education and awareness of the need to conserve biological resources, sustainable conservation of biological resources, management and planning strategies as goals. Biological diversity was clearly defined to include domestic animal breeds. Senior representatives from the federal and provincial governments, industry, universities, and the Canadian Agri-Food Research Council formed a steering committee called CANSTAG (Lister 1997). A group of experts from industry, academia, government, legal and animal care organisations, the Canadian Animal Germplasm Technical Experts Board (CAGTEB), met regularly for several years and produced a planning document for Canadian farm animal conservation (Lister and Ho 1995). The Canadian Foundation for the Conservation of Farm Animal Genetic Resources (CFCFAGR) was incorporated in early 1996, as a not-for-profit organisation, to serve as a catalyst for research, education, and similar efforts (Ho et al. 1997). One of the first recommendations of this group was for the development of a bibliography of the conservation literature (Hansen and Shrestha 1996) as many of these publications did not appear in the standard refereed scientific press. A communications strategy was put in place, and educational (Silversides and Patterson 1996) and promotional brochures were developed.

Rare Breeds Canada (URL http://www.flora.org/rbc/) is also a federally incorporated charitable organisation "dedicated to the conservation, evaluation and study of rare, endangered and minority breeds of livestock and poultry". The structure began as Joywind Farm Rare Breeds Conservancy, an organisation developed primarily by Jy Chiperzak in Marmora, Ontario. The formal name change was made in 1995 following some major restructuring. Membership as of April 1999 was 610, with more than half of these in Ontario. However, the organisation appears to be growing, with new chapters forming in several provinces and links to international groups. It oversees a Host Farm program to assist in rescuing and increasing the populations of breeds of animals that are of historic significance in Canada. The quarterly publication, Genesis, includes articles from producers, descriptions of rare breeds, and advertising.

A modification of in situ conservation is in the use of historic breeds of animals in farm parks or agricultural museums. Shirley (1995) among others, described such a system in the United States, in Colonial Williamsburg. The Ukrainian Cultural Heritage Village near Edmonton has just acquired two Oxford sheep, a breed low in numbers in Canada and listed on the ALBC Watch list. Unfortunately, the period represented by these historic sites can create some problems. In Nova Scotia, the Fortress of Louisburg would like to keep poultry breeds representative of the mid–1700s, such as Game birds, while Ross Farm portrays a period a hundred years later and prefers Hamburgs (Martin 1986). However overlaps should be encouraged (both groups could keep Dorkings) and all sites should be integrated into a national and international strategy for breed preservation. Although a few Canadian sites are listed in the American based Farm Museum directory (Association for Living History, Farm & Agricultural Museums 1998) there is no comprehensive listing of those which actually keep heritage breeds. Development of such a listing would facilitate interchange of ideas and of genetic stock. To assist in public education and fund-raising, a "coffee-table" book of photos of Canadian breeds, such as that by Alderson (1994b) on British rare breeds, or the ALBC (Christman et al. 1997) for American breeds would be a valuable endeavour.

Canada is not alone in being slow to recognise that domestic animal breeds are part of the United Nations convention. Rege (1997) stated that conservation efforts in Africa for livestock genetic resources were at least two decades behind those for plant genetic resources and wildlife. The International Livestock Research Institute (ILRI) thus initiated an Africa-wide research programme in 1992 to identify and characterise indigenous breeds. Over the past few years the FAO has become the focus of domestic animal conservation. The FAO Global Strategy for the Management of Farm Animal Genetic Resources provides an intergovernmental method for policy development, an infrastructure and technical program to help countries plan and maintain strategies, and a reporting and evaluation system. The main communication and information tool, DAD-IS, the Domestic Animal Diversity Information System, provides searchable databases, a library of resources, links to other sources, and lists of contacts. Although some of the databases are still under construction, you can easily determine, for example, that Canada has 7 species of cattle, 10 breeds of chickens, 13 breeds of horses, and 6 breeds of pigs that are considered to be in need of monitoring, while Mainland China lists 32 breeds of cattle and 118 breeds of swine. Entry of information is done by the country itself, which is responsible for the accuracy and completeness of the data. However, a coordinator's manual is available (FAO 1998) as are two manuals on technical guidelines for use by individual countries in planning. Manuals are available from the DAD-IS web site (http://dad.fao.org).

The European Association of Animal Production has been active in animal genetic resource conservation. Meetings were held throughout 1987 and 1988, with geneticists from Scotland, Norway, Finland, France, Italy, Spain and the Netherlands participating. With input from FAO, the results of the 1998 discussions were synthesised into a guidebook on genebanks and how to conserve domestic animal diversity (Oldenbroek 1999). Notter (1999) has also published an excellent overview of animal genetic resources and the opportunity for maintaining and using genetic diversity in long-term programs, focussing on the United States situation. Canadian animal scientists could begin discussions from these frameworks, and begin to take a more active role in maintenance of genetic diversity.

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The government of Japan supported a 4-yr pilot project in 12 countries of Asia and the Pacific through a trust fund to FAO, to coordinate and encourage management of genetic resources (Sarmiento et al. 1998). Limited funding is of course a problem, but training of national coordinators and of decision makers is vital if the conservation process is to continue.

Many landraces are poorly characterised, at least in written form. It is important to define production characteristics of breeds to assist in decisions on conservation, and to help define potential niches. For example, the ALBC is overseeing an effort to have poultry breeds characterised (Hawes et al. 1999) by asking producers to collect reasonably standardised records and submit them to ALBC. Canadian groups should coordinate their activities with such endeavours to ensure the breeds we are most concerned with are represented.

There is increasing work being done in the developing nations on characterising local breeds. Agyemang et al. (1991) examined milking characteristics of N'Dama cattle in The Gambia by monitoring almost 1500 cows in 45 village herds over a 5-yr period. 95% of the cattle in The Gambia are of this breed, used for much of the trypanotolerance research in the 1980s and still a focus for such studies (Trail and d'Ieteren 1992). Trypanotolerance in a breed allows that breed to survive and remain productive in tse-tse fly infested areas of Africa without the use of drugs. Tawah et al. (1997) described an unusual breed, the Kuri cattle in the Lake Chad basin, which is uniquely adapted to a flood-retreat farming and fishing system. The animal has bulbous horns which aid it in feeding on water weeds. This breed is highly regarded for its reproductive ability and its meat quality, but unfortunately is declining in numbers and has been extensively crossed with zebus.

Techniques of Breed Conservation

Setting up a scheme to conserve a breed should be multi-faceted. Toro and Maki-Tanila (1999) outlined a number of criteria that would allow for maximum variability in the conserved population. A first step is to select the animals that will be founding parents by choosing from as wide a range of families as possible. If pedigree information is available, as it is for many of the pure breeds in the developed world, the task is reasonably straightforward. For example, in Canada we can access the breed registry kept by the Canadienne Cattle Society or check for the genetic relationship of one registered Berkshire pig to another. However, in many cases paper records of pedigrees have not been kept. We may need to rely on historical records or consult with producers as to sources of breeding stock. Molecular biology will allow us to characterise the genetic relationships and monitor pedigree claims. Since this can become complex, computer software packages have been proposed for helping choose among strategies (Woolliams and Meuwissen 1999).

In any case, an accurate and unique individual identity code is needed. Such a mechanism exists in Canada through the Canadian Livestock Records Corporation. As well as handling purebred registrations, this group now offers a service to owners to identify non-purebred animals. Thus, the system allows for registering animals which could not otherwise be registered under the Animal Pedigree Act. The national identification programs being developed now to monitor health status, such as the National Cattle Identification program, may also provide an avenue to comprehensively identify animals. This would avoid the cost of setting up duplicate systems; however, the various industry groups would need to reach agreement.

Technologies such as artificial insemination and embryo transfer are now widely used in the bovine species. Unfortunately, these techniques have limitations in other species. Frozen semen from sheep, horses and swine has poor sperm motility on thawing and sheep are difficult to inseminate. Poultry semen is also difficult to freeze. Cryostorage of ruminant embryos is now routine, but freezing of porcine and poultry embryos still presents problems. Although this will probably never be as straightforward as maintaining plant seed banks, cryopreservation schemes can serve as useful backups for other conservation methods in many species.

Biotechnology offers opportunities for preserving genetic resources. Schmutz (1995) outlined the benefits of using biotechnology both to better characterise breeds and to conserve them. Her argument was that morphological traits such as colour and horn type only give part of the picture; DNA technology can help to characterise genetic diversity at the level of the allele. This is particularly important for traits such as disease resistance. Gibbons (1995) highlighted the benefits of knowing which genes govern important production traits at a workshop on farming food in the future. The Expert Committee on Animal Reproduction (Lister and Grunder 1998) also reviewed the benefits of biotechnology in conserving genetic resources in a recent report presented to the Canada Committee on Animals.

However, others (Kloppenburg and Burrows 1996) argue that biotechnology is too influenced by private interests, and these interests are often incompatible with ecologically sound and socially just agriculture. These authors state that in the United States 75% of research and development is undertaken by the private industry. New genetic technologies are being developed in industrialised countries in corporate or academic labs, to suit their purposes, and should be left there. They claim that companies such as Monsanto and USAID are distributing "surplus biotechnology". This may require the recipients to participate in a global market for which they are not well prepared.

About 70% of the world's biodiversity exits in underdeveloped countries, in many of which loss of control of their own genetic resources is becoming a concern. Issues of interpretation of the Convention on Biodiversity, especially Article 16(1), paragraph 20, arise. Sihanya (1994) outlined several steps that governments can take to ensure these countries will benefit from the treaty. Agencies involved with conservation must have the technological and business expertise to deal with issues and this requires that development aid include training local people. Another requirement might be that research on techniques is conducted in the country which is the source of the genetic material.

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However, scientists are now being actively recruited to work on molecular genetic characterisation of breeds in developing countries. For example, ICARDA, the International Centre for Agricultural Research in the Dry Areas, advertised in the May 1999 *Journal of Animal Science* for a molecular geneticist to design and implement studies to help determine genetic relationships among breeds of small ruminants in Central and West Asia and North Africa, and to identify quantitative trait loci and major genes for traits associated with production, environmental tolerance, and disease and parasite resistance.

Cloning is one of the newer techniques of potential value. The greatest advantage of cloning is to quickly spread genetic merit through populations, with a somewhat lesser benefit of being able to create additional genetic progress. A number of studies on the effect of cloning have looked at levels of inbreeding. However inbreeding only indicates the degree of genetic change within a breed, the parent diversity. Woolliams and Wilmut (1999) examined the impact of cloning on genetic variation in general, including breed diversity, parent diversity, local diversity and diversity within individual animals. These authors found that if incorporated properly into a breeding scheme, the rate of genetic progress could be increased without reducing parent diversity. However, although the increase in genetic merit by cloning has many advantages for commercial breeding companies, this requires a high level of technical expertise and an organised testing system. This could result in loss of genetic merit in all traits in local areas, for example on a single farm or in a particular region. Woolliams and Wilmut (1999) felt that this would be a particular concern if diseases arise in these areas.

When a population has shrunk to only a few animals, cloning may be the only option left. Wells et al. (1998) used adult somatic cell nuclear transfer to clone the last remaining female of a breed of cattle adapted to a sub-Arctic environment. Sperm from nine bulls had also been frozen. Elsie, the resulting calf, represents a chance to maintain the breed, even though this is a limited genetic base.

Decisions on which breed to conserve can be aided by mathematical techniques. The Weitzman approach uses maximum likelihood and evolutionary trees, and has been used for wild populations (Beardmore et al. 1997) and for European cattle breeds (Thaon d'Arnoldi et al. 1998). The latter study concluded that if we were willing to relax breed standards and consider amalgamating some endangered breeds with others, we could avoid direct loss of alleles without incurring additional costs. There has been a great deal of work on developing optimal composition of a synthetic line to exploit the advantages of the contributing lines. This includes theoretical studies accounting for genetic merit (e.g., Lin 1996), and methods to assist in ranking subpopulations according to the amount contributed by each to total genetic diversity (Finkeldy and Murillo 1999).

CONCLUSION

Maintenance of biodiversity should consider genetic, environmental, and social components. Genetic groups that are of little value in current animal production systems may well be needed in the future, to allow us to meet public and legal demands for more sustainable agricultural systems. Likewise, they may serve as sources of genetic material for scientific and medical purposes. It is important that we explore every avenue for conservation of such breeds, while recognising that we will not be able to keep all. We may never reach any consensus on which breeds to keep — a combination of individual interest and luck may well decide.

Given the general decline in government funding in Canada, we are unlikely to see a comprehensive program for preservation of genetic diversity for livestock and poultry species unless scientists, the agricultural community, and the general public all become involved. We need to connect local initiatives, support on-going activities, and encourage research scientists to use rare breeds in testing techniques in molecular genetics and reproductive biology. The Canadian Foundation for the Conservation of Farm Animal Genetic Resources, Rare Breeds Canada, the Expert Committee on Animal Genomics, Biotechnology and Reproduction and the Canadian Agricultural Research Council all have expertise in complementary areas. Continued interaction of such groups is needed to effectively plan strategy and search for resources. Time is not on our side — our livestock and poultry breeds are disappearing rapidly.

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